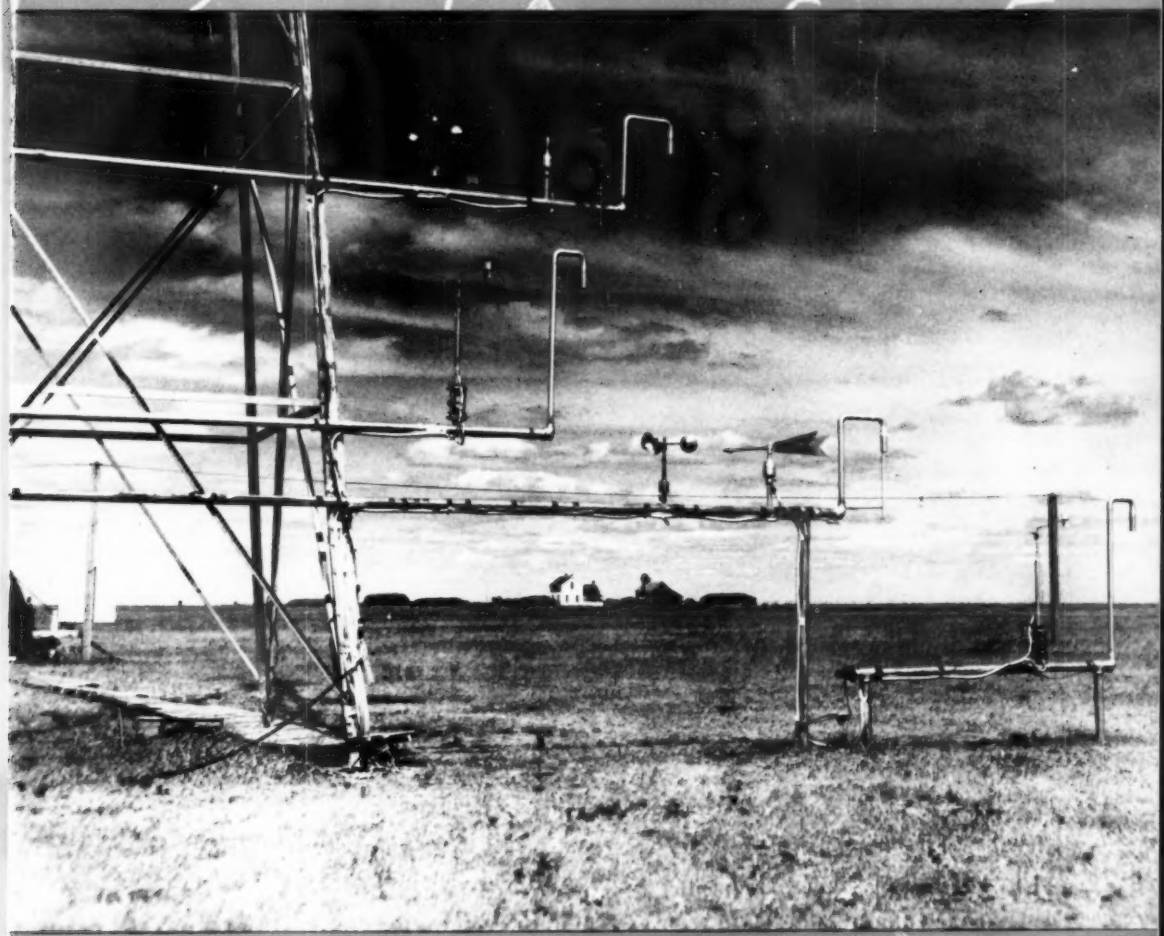
Weatherwise



Volume 6, Number 6 December 1953

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor*
HENRY W. BULKLEY, *Associate Editor*
HANS H. NEUBERGER, *Technical Editor*
ERIC SLOANE, *Art Director*

Ocean Weather Ships

The recent announcement of the intention of the United States Government to withdraw from the North Atlantic weather ship network is most distressing news. If the decision is not reconsidered or modified, a blackout of vast ocean areas will result, and we shall be thrown back to the dark ages of oceanic meteorology such as existed before World War II.

The reason given for the move is economy, and there can be no doubt that weather ships, according to the American practice, are expensive. Yet the expenditures should be judged in the light of accomplishments. The faculty in meteorology at New York University recently pointed out in a public letter that the chief benefit of the weather ship chain, even considering its great assistance in the field of forecasting and navigation, lay in the field of meteorological research. They emphasized that the maintenance of a complete hemisphere upper-air reporting system, only obtainable currently with the use of weather ships, had already yielded rich results toward a better understanding of our atmospheric processes.

The recent unpredicted coastal storm, which lashed the New Jersey and Long Island shores with unprecedented tides and covered the Middle Atlantic States with a record November snowfall, points up the need for more, rather than fewer, weather ships off the Atlantic Coast. The forecaster trying to predict the movement of a South Atlantic low has about as much data as the astronomer who wishes to study the other side of the Moon.

Surely, an economical way must be found to provide for the continuance of the weather ship chain. Suggestions have been made that a foreign government under contract or perhaps a private enterprise might maintain the service at less cost. A meeting is scheduled for Paris early in 1954. Let us hope that all possibilities will be explored.

Vol. 6, No. 6 December, 1953

CONTENTS

Snow Cover in Canada
— C. C. Boughner and J. C. Potter 155

Operation Hailstone
— Lee A. Jay, LeRoy F. Hafer, and Willis A. Wood 160

Flying the Weather Map with the Wright Brothers 164

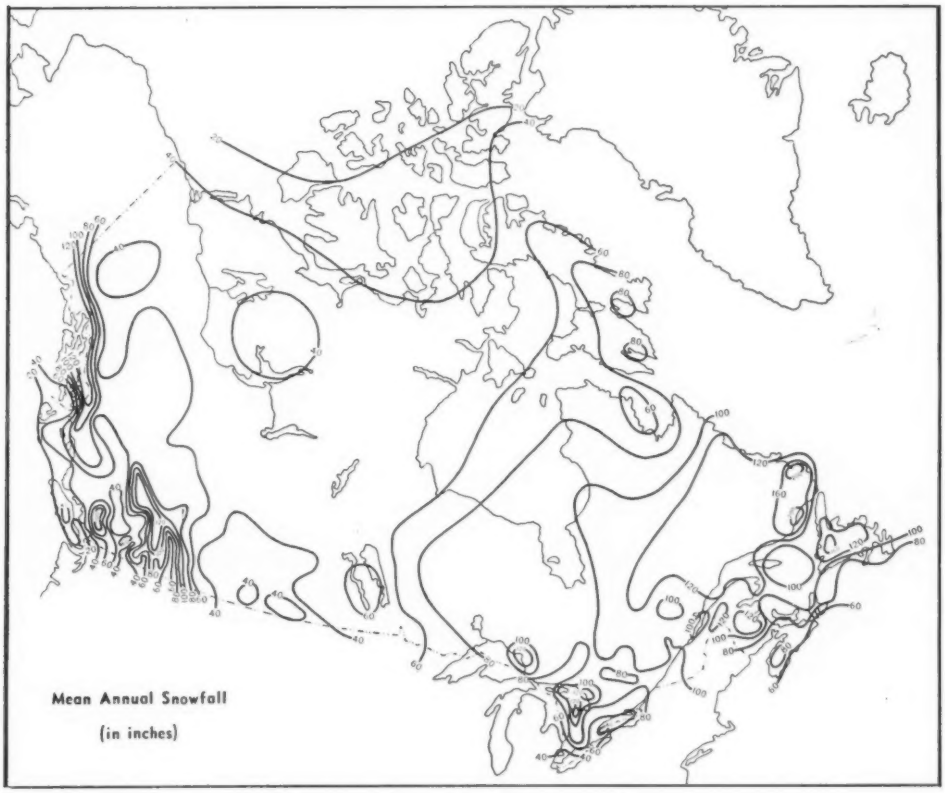
The Great Plains Turbulence Field Program
— Heinz Lettau and Ben C. Davidson 166

The End of the Prolonged Drought—?
— David M. Ludlum, editor 172

551.5 174

Cover: The scene at the Great Plains Turbulence project at O'Neill, Nebraska, shows part of the MIT installation. Standard wind instruments are mounted on the second and fourth booms, while special bivanes for micrometeorological work are on the first and third booms.

WEATHERWISE is published bimonthly for the American Meteorological Society. Office of publication, 3 Joy St., Boston 8, Mass. Subscription is $3.00 per year; add 50 cents for postage to Canada and all countries in the Pan-American Postal Union; add $1.00 for all other foreign countries. Subscription orders, claims for missing numbers, changes of address, and advertising correspondence should be addressed to the society at 3 Joy St., Boston 8, Mass. Editorial offices: Franklin Institute, Philadelphia 3, Pa.



Snow Cover in Canada

C. C. Boughner and J. G. Potter, *Meteorological Service of Canada*

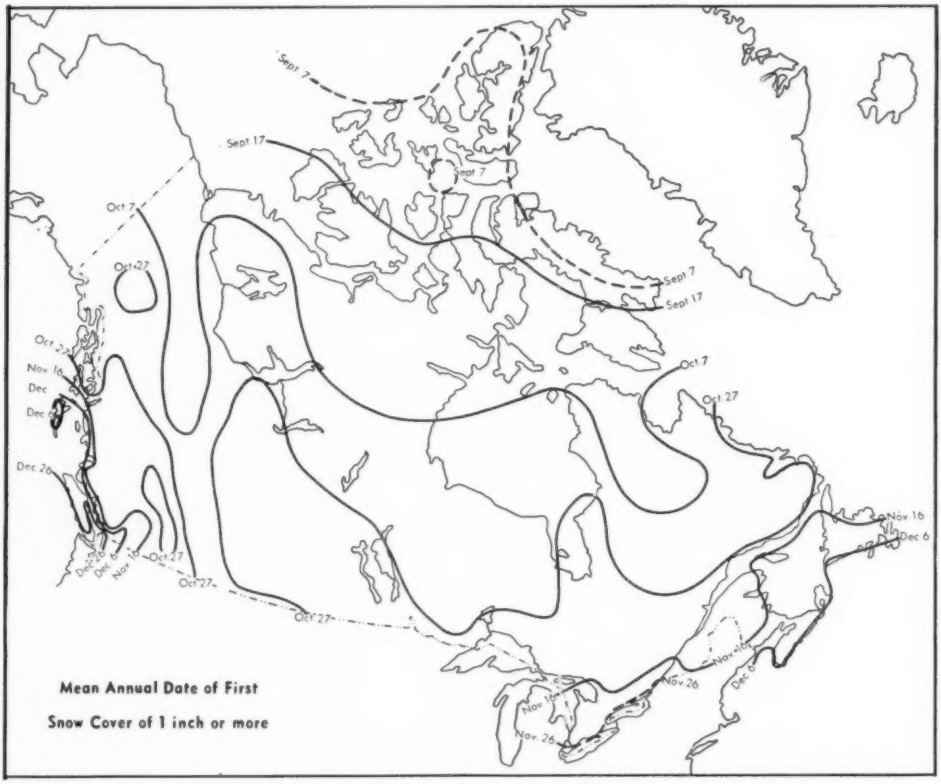
THE tapping of the rich iron ore deposits in Labrador, the building of the electric power plant at Kitimat, British Columbia, to supply power to the largest aluminum smelter in the world, and the discoveries of uranium ore in northern part of the Prairie Provinces have all focused world attention in recent years on the economic potentialities of the vast areas of northern Canada. This region is snowbound for a part of each year with all the difficulties that a snow cover presents to modern transport. The need for a study of the duration and varying depth of this snow cover has increased with the northward expansion in Canada, but only recently have representative records of sufficient length been accumulated to carry out this project. This article is a summary of some parts of a complete study to be published later by the Meteorological Service of Canada.

Since the depth to which snow accumulates on the ground is primarily dependent on the actual snowfall, a chart has been included to show the mean annual snowfall in Canada. Areas with an average winter snowfall in excess of 100 inches are confined to the interior of the island of Newfoundland, the greater part of eastern Quebec and Labrador, northern New Brunswick, the lower St. Lawrence River valley, the area along the eastern shores of Lakes Huron and Superior, and the windward slopes of the mountains in British Columbia. In eastern Canada, the greatest winter snowfall normally occurs between 50° N and 55° N

with large areas of eastern Quebec and Labrador receiving 10 to 15 feet of freshly fallen snow during the winter. The snowfall normally decreases northward from this region. In contrast to eastern Canada, the average winter snowfall throughout the Prairie Provinces and the Mackenzie River valley is remarkably uniform and is much the same as over the northern section of the Great Plains of the United States. The Arctic Archipelago receives snowfall much lighter than most people realize, since over its northern fringes the seasonal snowfall is comparable to that of Washington, D. C., or St. Louis, Mo.

Permanent snow fields are found in Canada only on the higher elevations of the Rockies, on Baffin Island, and on other smaller islands in the eastern Arctic. The average date of the first snow cover of one inch or more along the fringes of the Arctic Archipelago occurs during the first week of September as shown in an accompanying chart. All the islands of this region receive their first snow cover before the end of September. During October the influence of Hudson Bay is noticeable in retarding the formation of the snow cover along its eastern shore. In the general northwesterly flow, the warmth of the water retards the arrival of the snow by 10 days or more compared to the interior of northern Quebec where the snow line progresses rapidly southeastward to reach the north shore of the Gulf of St. Lawrence by the end of the month. The warm waters of the Gulf and of the Atlantic Ocean delay the formation of the first snow fields over the Atlantic provinces by about two weeks, and it is not until the end of the first week of December that the first snow cover is observed along the Atlantic coast of Nova Scotia.

West and south of Hudson Bay, the general southward advance of the snow cover is more rapid and regular than in eastern Canada. Although the line marking the date of the

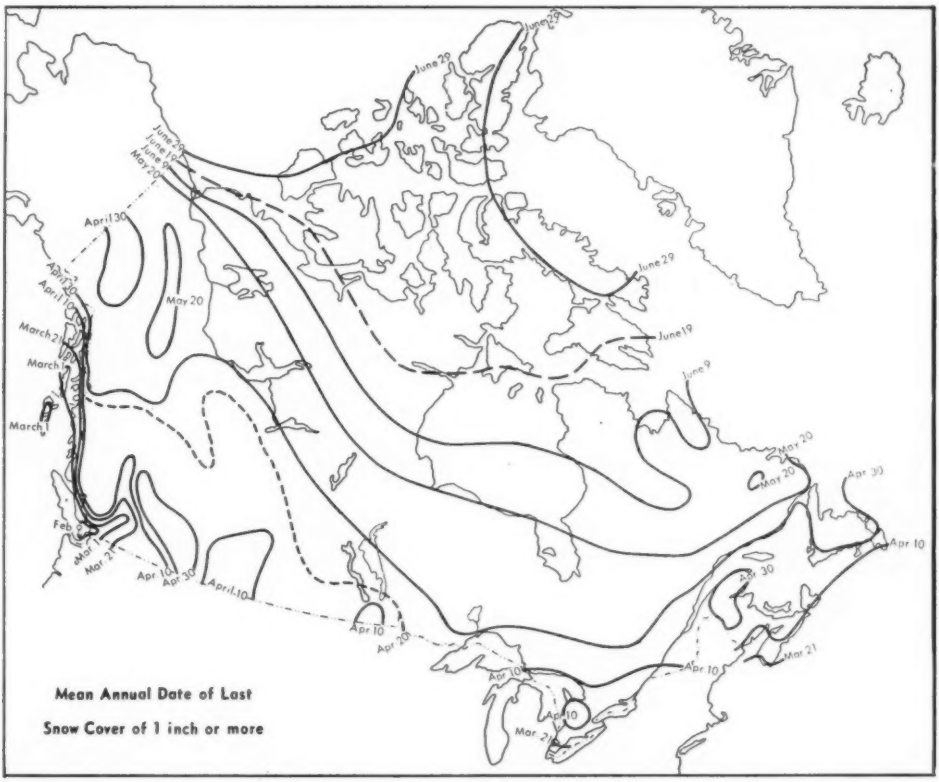


first snow cover has barely reached the Arctic coast of the mainland at the beginning of October, by the end of the month it is close to the north shore of Lake Superior, and by the end of November it has moved south to Lake Erie.

Over the District of Mackenzie and the Prairie Provinces, the appearance of the first snow cover is remarkably uniform. In an average winter, the first snow cover appears over all this region during the month of October with only three weeks difference between the date of its first occurrence along the shores of the Arctic Ocean and the southern borders of Saskatchewan and Alberta. In the foothill country of Alberta the higher elevations experience early heavy snowstorms that give a temporary snow cover. Thus a snow is usually observed at Calgary only one week later than at the mouth of the Mackenzie River and one week earlier than in the vicinity of Great Bear Lake.

In British Columbia the only available data are from valley stations, and it is impossible to discuss all the variations imposed by altitude. In general, the date of the first snow cover progresses southwestward down the Fraser River valley from the interior plateau to the coast during the months of November and December. At Vancouver during three out of 10 winters the snow cover did not reach one inch. At Victoria, on Vancouver Island, a similar situation held for four out of 10 winters, and on the western coast of Vancouver Island more than half the winters passed without the formation of a snow cover of one inch in depth.

An accompanying chart portrays the mean maximum depth of snow on the ground measured during the entire winter. For these measurements the observers are instructed to take their observations in an area that is not drifted. Thus the data are representative of the average prevailing conditions in non-



Feeding a tame fox at one of the most northerly weather stations in Canada. The picture, taken at the time of deepest snow cover, shows the hardness of the snow cover in the Arctic and the bare ridges in the background. Courtesy of Arctic Weather Section.

drifted areas. The most striking feature is that there are very few sections of Canada that do not have more snow on the ground at some time during the winter than does the northern part of the Arctic Archipelago. Even during the winter months, hills and ridges in the Arctic are swept bare of snow as it is continually shifted by the wind. Normally the maximum accumulation of snow in the Arctic islands is reached toward the end of May and averages about 10 inches. The deepest snow cover reported at any of the Joint-Arctic weather stations since their establishment in 1947 was 21 inches at Resolute in late May 1948.

The sections of Canada having the least and greatest accumulation of snow on the ground during the winter are both located in British Columbia. Surveys show extensive areas in the higher elevations of the Coast Ranges where depths of 30 feet or more are likely, whereas somewhat further west, on the western coast of Vancouver Island, there is less than a 50 per cent chance of the depth of snow reaching even one inch during the winter.

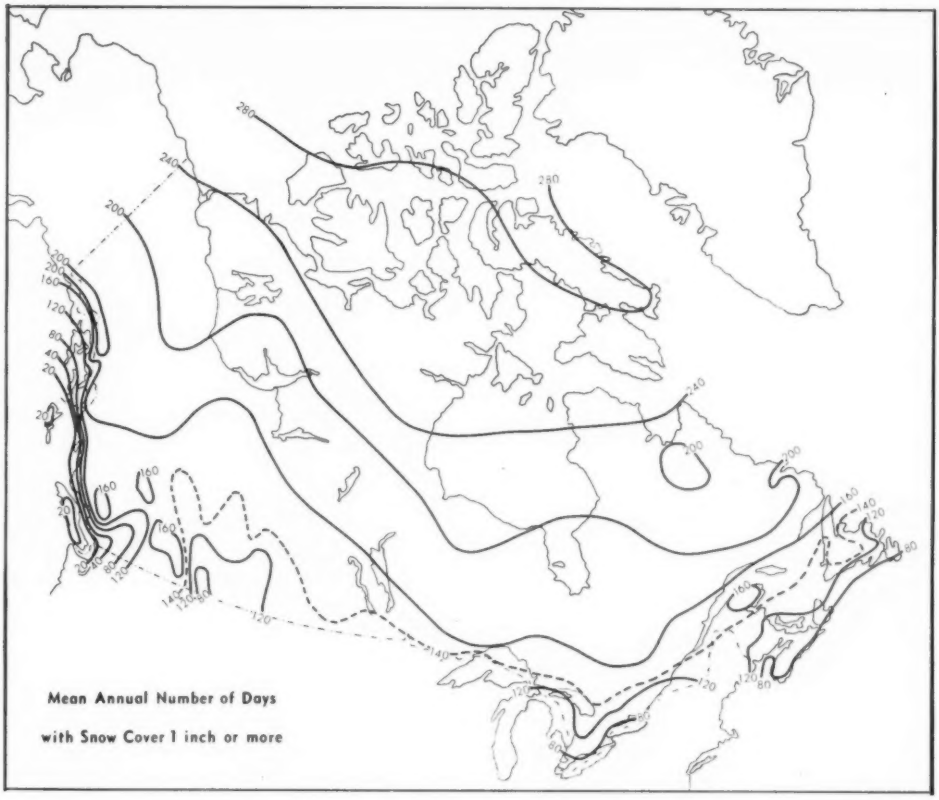
Over the large area of the three Prairie Provinces and the District of Mackenzie there is little variation in the average maximum depth of the snow fields. In an average winter snow accumulates to a depth of about 20 inches over this region. The severest winters produce a maximum snow depth of two to three feet, while the most open winters will give a maximum depth of only 12 to 18 inches in the north and not more than two to five inches along the international border. Eastward from the Prairies the snow cover becomes deeper with the general increase in total snowfall. Portions of central Quebec and southern Labrador accumulate more snow on the ground than any other part of North America with the exception of the west coast mountains. In the average winter the mean

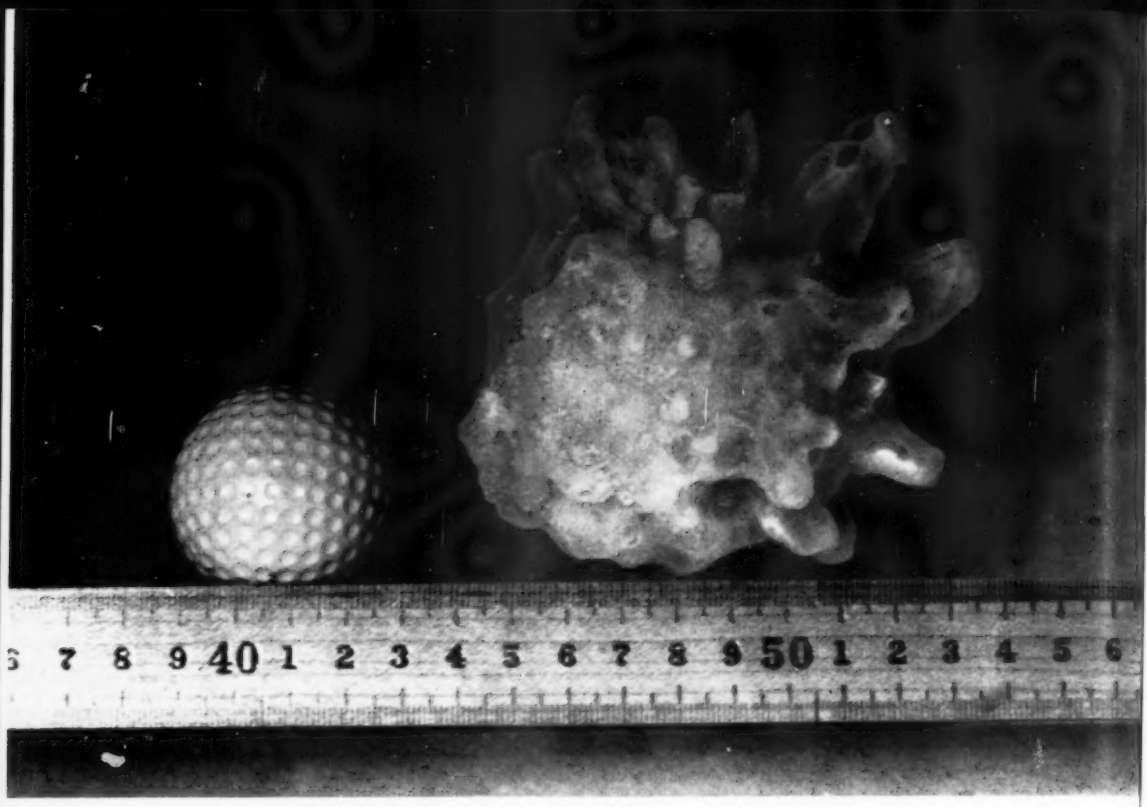
snow depth reaches five feet, with seven to eight feet accumulating in extreme winters. The railroad over which the iron ore from Labrador is moved to Seven Islands on the Gulf of St. Lawrence lies in this region. The above figures will give some idea of the difficulties that would be encountered in an attempt to transport the ore during the winter season.

The change from winter to spring conditions with the melting of the snow does not coincide with the official coming of spring on 21 March except in a very small portion of Canada. A fourth chart gives the average date of the last snow cover. In most sections this is the date of the last heavy snowstorm and is usually one to two weeks later than the disappearance of the continuous snow cover which exists throughout the winter over most of Canada. During April the snow line recedes irregularly northward and by the end of that month is roughly along the 49th parallel in eastern Canada, swings northwestward over the Prairies, and is north of 60° N in the Mackenzie valley. In May the snow line moves down the Mackenzie River to the vicinity of the Arctic Ocean, but in eastern Canada the northward recession is retarded by the deeper snow cover and the cool weather resulting from the frequent outbreaks of Arctic air. With increasing sunshine in June the retreat of the snow line again accelerates, and by the end of the month the snow has disappeared from most of the Arctic Archipelago.

A fifth chart shows the average number of days in each winter on which the ground is covered with snow. This varies from 10 months in the Arctic to less than one week along the southern coast of Vancouver Island. The line for 140 days duration has been added east of the Rockies, as the northern limit of successful agriculture in Canada lies in the

(*Continued on page 170*)





The largest hailstone recovered compared with a golf ball and a meter stick.

Operation Hailstone

LEE A. JAY, LEROY F. HAFER, AND WILLIS A. WOOD
U. S. Weather Bureau, Washington, D. C.

THE Weather Bureau forecast of "rather cloudy with scattered thunderstorms today and highest temperature in the middle 80's" received no unusual attention from the populace of Washington, D. C., and nearby areas on the bright and cheerful morning of 26 May 1953. Meteorologists, however, were busy scanning the 0730 EST weather map and noted that a 1005 mb low was centered near Buffalo, New York, with a short occluded front in New York state, a warm front curving south to Washington and then east to the Atlantic Ocean, and a cold front extending from north-central Pennsylvania westward through central Indiana. With moist and unstable tropical maritime air to the south of the frontal system and polar continental to the north, the prospects for thunderstorms were good.

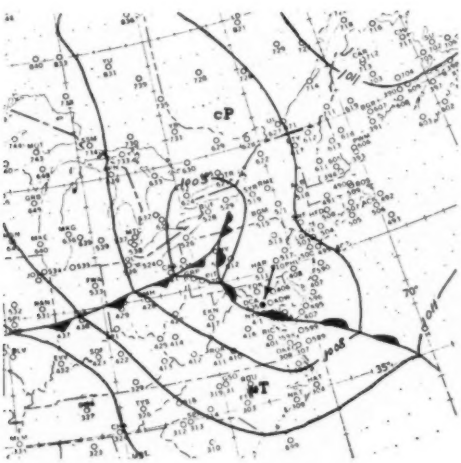
By early afternoon the map indicated that the cold front had moved to within less than 100 miles of Washington. At 1400 following several hours of scattered to broken high, thin clouds, the Weather Bureau station at the Washington National Airport reported cumulus clouds to the northwest. One-half hour later cumulonimbus clouds appeared to the northwest in Maryland and soon developed into a severe storm, moving rapidly across the District of Columbia from the northwest to the southeast and into Maryland again in the vicinity of Suitland at a speed of approximately 40 mph. The Central Office at 24th and M Streets, N. W., was on the edge of the storm and received only a brief rain shower with gusty wind at 1515. Near the center of the storm, however, hail fell for about five minutes followed by 10 minutes of heavy

rain in large drops. The hail included a generous number of unusually large stones, the largest on record in the area.

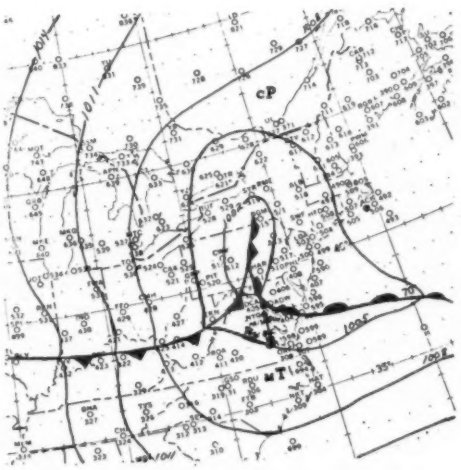
After the storm many of the larger hailstones were picked up and placed in freezers. Although the hailstones had undoubtedly melted somewhat while remaining on the warm ground in the rain, it would have been foolhardy for anyone to venture out in the storm. A woman, attempting to save some clothing hanging on an outdoor line, had a hailstone pass through her umbrella and strike her head, requiring four stitches in the scalp wound. Of the many salvaged stones that were presented to the Weather Bureau the largest had a maximum diameter of 4⅛ inches and weighed approximately seven ounces, and many others were nearly three inches in diameter. One stone was cut in half in order to ascertain whether it was one large hailstone formed around a single ice core or merely a conglomerate mass of several small stones. The center was composed of the familiar white "onion rings" common to most hailstones, while the outer portion consisted of nearly transparent ice. Approximately two-thirds of the surface was covered with "fingers" of the clear ice protruding from the main ice mass. Observers reported that this hailstone, and many others like it, fell as rough stones and that the projections were not the result of uneven melting on the ground. Other stones were in the shape of doughnuts with clear ice centers or with the center hollow.

According to one theory of the formation of hailstones, a raindrop is carried aloft by an updraft and freezes in the cold upper portion of the cloud. The small newly-formed hailstone collects frost and snow and, tumbling out of the ascending column of air, falls to a lower level. In the lower and warmer regions of the cloud, the hailstone collects a layer of water which freezes to the very cold ice. According to this theory, the size of the stone is regulated by the number and duration of the traverses it makes from the bottom to the top of the cloud. At any rate, the rings indicate the number of times that the growing hailstone came alternately in contact with supercooled droplets and frozen cloud elements. It is evident, therefore, that the size of the largest stones in any storm partly depends upon the ability of the updraft to maintain the stones in the freezing layers of the cloud. It is estimated that an updraft of at least 115 mph is required to support a hailstone three inches in diameter.

The large stone described above had a central core three inches in diameter exclusive of the projections of clear ice. It should be noted, however, that the updraft need not support the full-sized hailstones in all cases, since their size may increase on the final



A sectional weather map for 0730 EST, 26 May 1953.



A sectional weather map for 1330 EST, 26 May 1953.

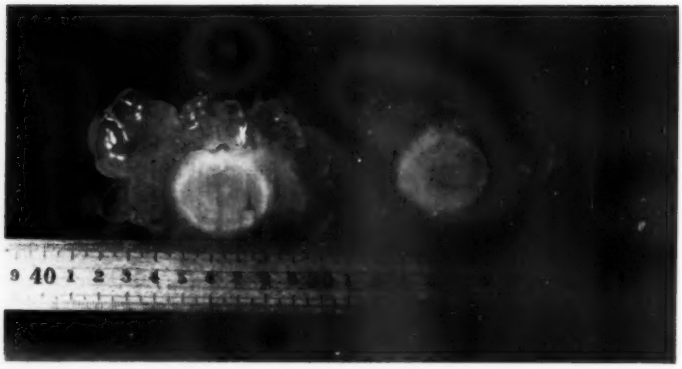
descent through the supercooled portion of the cloud. It seems reasonable to assume that in a violent thunderstorm some of the hailstones fall through zones of large raindrops at or near freezing temperatures. The hailstones then collect considerable quantities of water that freeze into clear ice. If some of this water flowed around the balls of ice, it would freeze into trailing fingers of ice on the sides and backs of the hailstones in the manner of icicles. Small imperfections on the surface of the stones might act as stabilizing rudders until the growths of ice formed. It is believed that the large hailstone previously described was formed in this manner. Other stones falling from various portions of the thunderstorm would be affected by slightly different conditions with resulting variations in structure. The formation of the doughnut-shaped hailstones observed has not yet been fully explained; one theory maintains that they were formed while spinning or rolling down the side of a strong updraft.

Several of the hailstones were examined for radioactivity. The results were inconsistent, as some tests indicated a level of radioactivity less than that of normal rain water, while a few tests indicated a relatively high level of activity. The radioactivity was believed to be within the variable limits normally observed with precipitation particles.

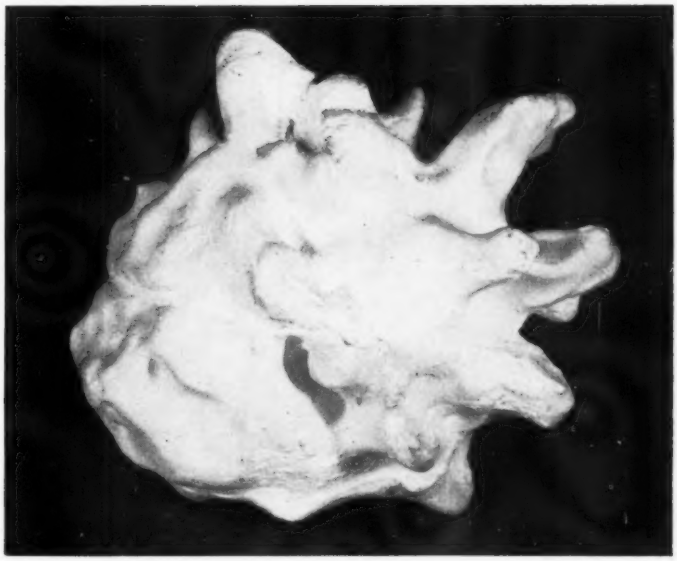
A pressure jump of .06 inch accompanied the passage of the storm at the Central Office at approximately 1500, when the wind shifted from west to north with gusts to 44 mph. The temperature fell from 91° to about 80° at 1515 when the rain shower occurred though only .01 of an inch of rain fell.

There phenomena would seem to indicate that the cold front had passed; but this was not the case, because the pressure fell again, and the wind returned to the west and became very light. At about 1645 the wind became gusty and again shifted to the north, and the relative humidity and temperature dropped after 1700. Accordingly, it seems that the hailstorm occurred on a squall line in advance of the cold front. This is further substantiated by the radar echoes observed at the Weather Bureau station at the National Airport. The thunderstorm produced one unusually large and bright echo while in the Washington area, but, as it moved to the south, the large echo split into a line of smaller echoes and took on the usual appearance of a squall line.

On the basis of insurance settlements and other reports the hail damage to buildings and automobiles has been estimated at about $200,000. Over 1,200 windows are known to have been broken. Reports of damage were received mainly from an area about three miles wide and 15 miles long and were especially concentrated in a zone slightly over a mile wide and approximately three miles long. The damage reports do not indicate the true character of the hailstorm, since the density of residences is much greater in the area of heavy damage than at Suitland, Maryland, for example, where the largest hailstones were found, but only light damage was reported. Reports of small hail from this storm were received from an area extending several miles to the east of the edge of the damaged area. The large hail appears to have been concentrated near the western boundary of the hail producing zone of the thunderstorm, as no small hail fell to the



The two halves of the large stone shown on page 160. Note the concentric rings in the white center portion and the nearly clear ice of the outer shell and projections.



A plaster of Paris replica of the large hailstone illustrated on pages 160 and 162 (before waxing).

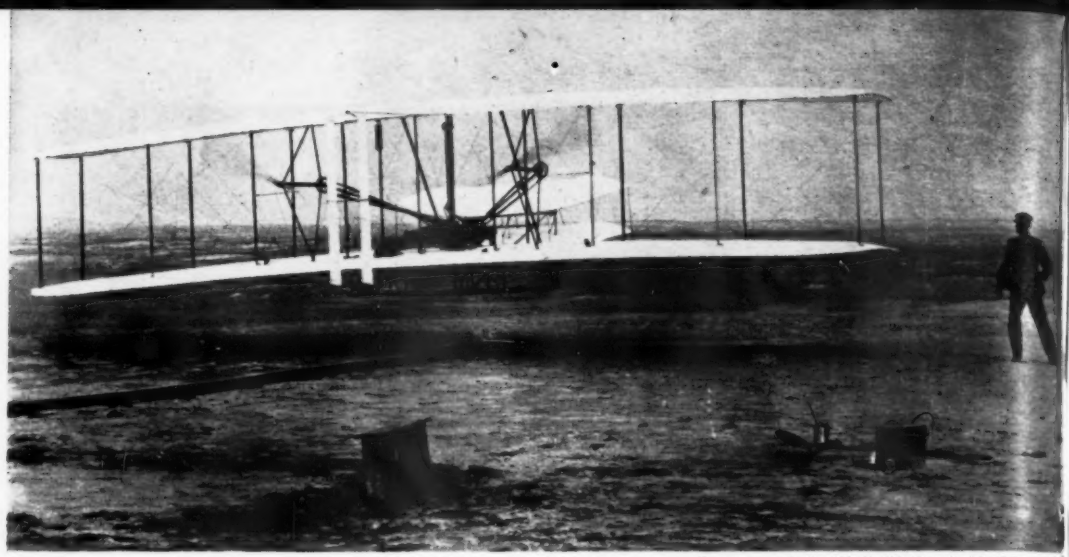
west of the damaged area.

The large hailstones collected by the Weather Bureau from various sources were kept in a box containing dry ice until they were photographed and identical replicas produced. Several methods of making replicas were tried, using ice cubes instead of hailstones. The simplest method and the one finally used to make the exact replicas is described here. The materials used are readily available in most areas.

A container of melted paraffin was placed in one corner of the box containing the hailstones and dry ice. Before the paraffin began to solidify, a thread was tied around the hailstone and the hailstone was quickly dipped into the paraffin, immediately removed, and held near the dry ice. This prevented any melting of the very cold hailstone. The dipping and cooling process was repeated eight or ten times until a ⅛-inch coating of wax covered the hailstone. The hailstone was then placed on the dry ice until the wax became thoroughly solidified.

The wax-coated hailstone was then suspended in a cardboard box into which some plaster of Paris especially prepared for painters was poured until the entire stone was covered. After the plaster of Paris hardened, the mold was cut in two and the melted hailstone poured out. Several stones had large projections that would have made it difficult to remove the cast from the mold. These molds were cut into four, six, or eight sections.

The section or sections comprising the two halves were filled with a mixture of plaster of Paris, the mixture being kept sufficiently thin so that it flowed into all parts of the mold. When the plaster of Paris began to settle, the two halves were tied together. After one hour the entire cast was placed in melted paraffin for several minutes until the inner wax coating softened sufficiently to remove the sections of the mold without breaking the cast. Several replicas of the various stones were made in this manner. The casts were dried for several days and then were dipped into hot paraffin and quickly removed. All excess paraffin was shaken from the models. The resulting thin coat of wax protects the plaster and gives the cast an "ice" appearance. One model was given a special treatment. It was painted with two coats of common white enamel and then rubbed with an aluminum-based powder until a glaze formed over the surface. This method produces a very permanent finish, but for general use the wax coating will be satisfactory.



Courtesy of the U. S. National Air Museum

Flying the Wea

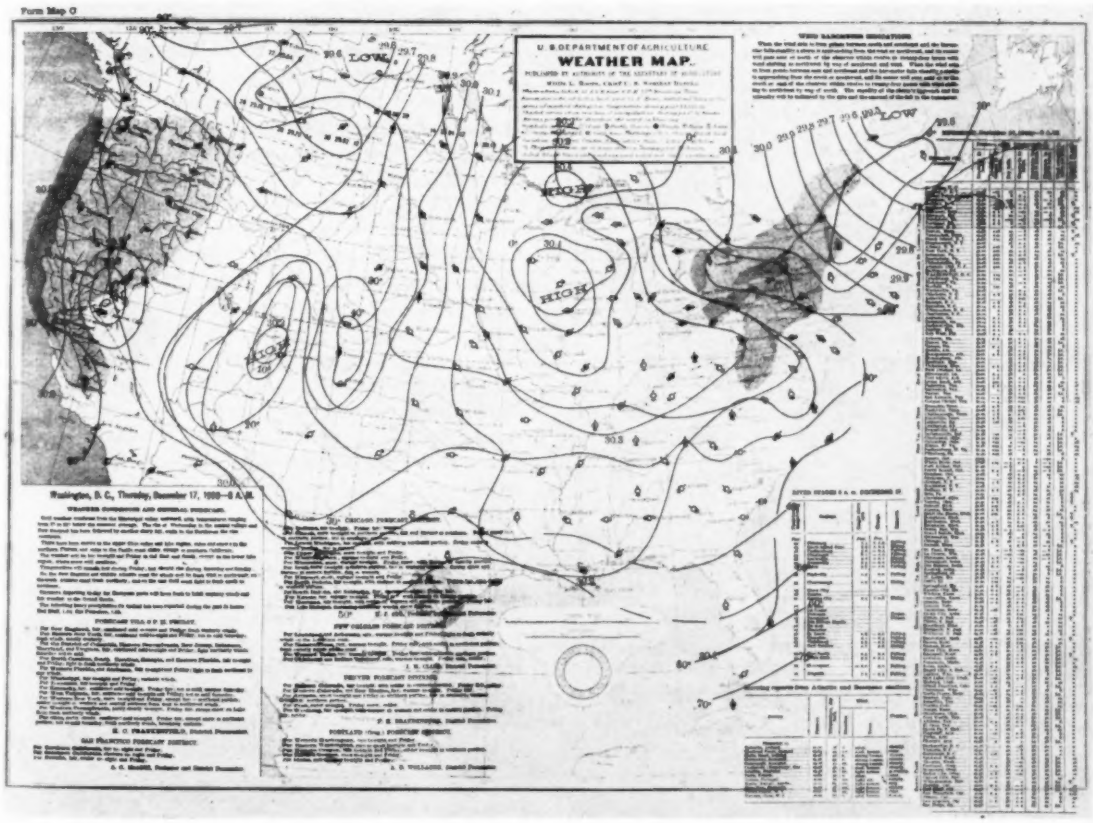
KITTY HAWK
17 DECEMBER 1903

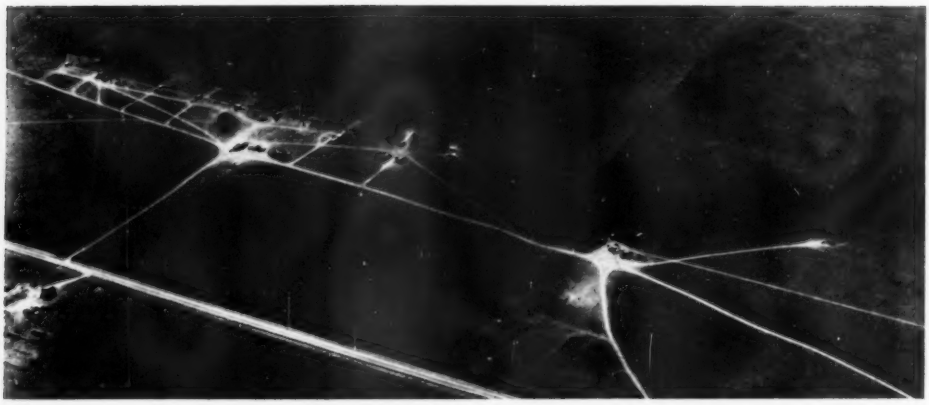
THIS month marks the 50th anniversary of the first successful powered flight across the sand hills near Kitty Hawk, North Carolina. This site was selected by Orville and Wilbur Wright after a long search for favorable meteorological conditions. Here is an "on the spot" description of the event as related by the Weather Bureau observer at Kitty Hawk, which appeared in the December 1903 issue of the *Monthly Weather Review,* under the heading of "Meteorology and the Art of Flying."

"During the past four years a series of most interesting experiments have been going on on the coast of Dare County, N. C., not far from the Weather Bureau Station at Kitty Hawk. Here the brothers, Wilbur and Orville Wright, of Dayton, Ohio, have established a camp and all the necessary apparatus for experiments in what is known as gliding flight. The apparatus, which is a form of aeroplane, is launched from the summit of a sand hill, and after making a long glide finally comes to rest on the sands below. After several years of experience and careful study of the currents and winds that blow over the sand hills, the Messrs. Wright have applied motor machinery to their aeroplanes. Their success is undoubtedly due in great part to the preliminary careful study of the winds, and for this reason, although ma-

chinery is essential, yet we consider that meteorology also has played an important part in their work. Their latest official announcement is that on December 17 four flights were made. The wind record at Kitty Hawk was 24 to 27 miles per hour at 30 feet above the ground, but at the flying station it was about 22 miles per hour at 4 feet above the ground. These flights were made from the level ground, against the wind, with no assistance from gravity; after a horizontal run of 40 feet the aeroplane rose with the operator on a very gentle incline to a height of 8 or 10 feet from the ground, after which the course was kept as nearly horizontal as the wind gusts and the limited skill of the operator would permit, and the flyer made his way forward with a speed of 10 miles per hour over the ground, or 30 to 35 miles per hour relative to the air. The fourth flight occupied 59 seconds and the machine flew through a distance of 852 feet over the ground, or about three times that distance relative to the wind; it landed earlier than was necessary, owing to a slight error of judgment on the part of the operator."

Weather Map with the Wright Brothers





The scene at O'Neill, Nebraska, looking south-southeast from an aircraft.

The Great Plains Turbulence Field Program

BEN DAVIDSON AND HEINZ LETTAU
Air Force Cambridge Research Center

A SECTION of prairie land located some six miles east of O'Neill, Nebraska, was the scene of an elaborate series of meteorological experiments during August and September 1953. The land, which had been used primarily for haying and cattle grazing, forms part of a rather extensive flat area, almost devoid of trees and prominent obstructions for many miles around. Early in July the cattle were driven out to neighboring sections, and an advance party of meteorologists, technicians, and service personnel moved in to prepare the site. By the end of July a mobile electric plant was in operation, 12 tents or huts had been erected, and the group of experimental teams had arrived with their equipment which filled 10 trucks and instrument trailers. Project Great Plains was on its way!

The Project was conceived and organized by the Air Force Cambridge Research Center with the primary objective to study wind, turbulence, and diffusion in the lower 5,000 feet of the atmosphere. In order to simulate as nearly as possible the reliability and accuracy of wind tunnel measurements, an effort was made to conduct the observations under as carefully controlled large-scale conditions as are feasible when dealing with the free atmosphere.

The phrase "turbulent flow" is applied to fluids or gases in irregular motion. Anyone out in the open who feels the wind upon his cheek, or watches leaves or branches sway in the wind, will quickly agree that atmospheric motions near the ground are turbulent. This is to say that the wind blows in fits and starts, now weak, now strong, from this direction and from that. These turbulent velocity fluctuations are of intrinsic interest in themselves, since they affect the flight of objects and serve as primary diffusing agents in the atmosphere.

Diffusion refers to the mixing or spreading of properties which are thereby transported from regions of high concentration to regions of low concentration. The primary atmospheric properties involved in diffusion are suspensions, heat, moisture, and momentum. The primary sources or sinks of these properties are at the ground. For example, the ground heats up by day and the turbulent atmospheric motions spread the heat concentrated at the ground within the lower troposphere. The mixing or spreading action is similar to what happens after one puts sugar into a cup of coffee or tea. There is an initial high concentration of sugar at the bottom of the cup and very little elsewhere. As one stirs the coffee with a spoon, the sugar is distributed more or less uniformly. Actually,

one is creating turbulence within the cup, and the more vigorously the coffee is stirred, the more rapidly will the sugar be mixed.

How is turbulence created in the atmosphere? In the first place, the ground over which air passes, even the relatively featureless and flat Great Plains area, is a very efficient creator of turbulence. This type of turbulence is generally called mechanical turbulence. Secondly, as heat is received or lost at the ground, buoyancy accelerations begin to act on parcels of air, creating an additional source of irregular motion which is called thermal turbulence. Turbulent fluctuations of any air property accompany the gustiness structure of the wind.

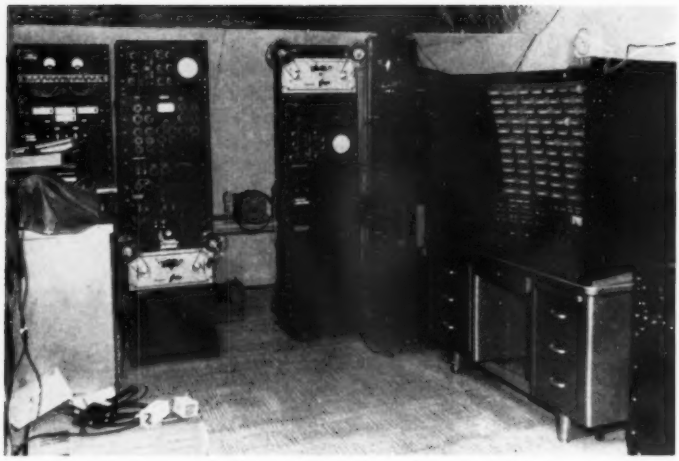
The objectives of the Great Plains Turbulence Field Program were to make a detailed, round-the-clock study of turbulent velocity, temperature, and moisture fluctuations and to relate these fluctuations to the local diffusion of atmospheric properties as well as to the dominant features of the large-scale weather map. The following controls were deemed essential: (1) A clear wind fetch over uniform terrain had to be assured in order to reduce the variations in turbulent fluctuations that are caused by nonuniform ground and the presence of obstacles. (2) Stable weather had to be awaited for situations where the direction of the isobars and the distance between them remained relatively constant over at least a 24-hour period. This condition of steady general flow was required to insure a steady mechanical turbulence in the absence of buoyancy effects. (3) Relatively clear weather for at least 24 hours was desired so that the diurnal range of heat added to, or subtracted from, the surface would be at a maximum. This latter provision was necessary to insure ample opportunity for studying the effect on turbulence of adding or subtracting thermal energy at the ground.

Because of university commitments, the program could be carried out only during the summer months. Synoptic-climatological studies for the summer months based on 10 years of 3-hourly USWB observations indicated that the August-September climate of the northwest part of the Midwest was most likely to yield a suitable number of observational days. The studies revealed that the climatological expectancy of an ideal observation day with persistent southerly flow is one per week, and that southerly flow at approximately 2,000 feet height may be expected slightly more than half the time. Topographical and land use studies indicated that Nebraska and South Dakota were very likely to provide flat sites of uniform cover. Several inspections of available sites in the area were made, and the final location was selected in December 1952.

A meeting was held at the Air Force Cambridge Research Center on 30 January 1953 to plan the program, and all branches of the Armed Forces, universities, institutions, and industrial firms known to be engaged in research in the field of atmospheric turbulence and diffusion were invited. The objectives of the expedition were agreed upon and experimental procedures and programs were discussed in detail. To insure an unencumbered wind fetch for each of the participating groups it was decided to operate under southerly flow conditions only. Hence the observation line was oriented east-west.

In general, the observational program consisted of:

A sensitive anemometer, designed and built at Iowa State College, is demonstrated by R. M. Stewart. Ping-pong balls, cut in half, form the cups which respond to very light wind movements. The horizontal bars above and below hold quick-responding thermistors to record very small temperature changes rapidly.



The electronic calculating equipment inside the Iowa State hut where the data from the fast-responding instruments was processed and analyzed. The Statistical Tabulator is at the right.

(1) Observation of turbulent fluctuation of wind and temperature with rapid-response instruments that permitted an observation at least once a second.

(2) Observation of the simultaneous fluctuations of wind and temperature in order to understand how wind fluctuations diffuse such properties as heat and momentum.

(3) Observation of the vertical gradients of wind, temperature, and moisture.

(4) Observation of the radiation energy received or lost at the ground.

(5) Observation of heat and moisture conditions in the subsoil.

It should be emphasized that standard instruments are inadequate to measure these variables with the desired accuracy. For example, the difference in wind speed over a height interval of 50 cm might be of the order of 15 to 30 cm/sec or 0.3 to 0.5 mph. The standard anemometer is not capable of sensing this difference accurately. Accordingly, this type of work requires a set of carefully matched lightweight anemometers having a minimum of friction. The ordinary mercury thermometer with its large lag is unsuitable for recording small differences of temperature accurately or for measuring rapid temperature fluctuations. Thermocouples made of very fine wires or very small thermistor beads, a form of variable resistance thermometer, must be employed. Wind speed fluctuations are measured with hot-wire anemometers or with a sonic anemometer, a device that times the difference in the arrival of sound pulses simultaneously originating from two sources, the difference in arrival time being proportional to the wind speed. A three-dimensional wind direction picture can be obtained with the aid of a bivane free to rotate in both the horizontal and vertical planes.

It is obvious that considerable research goes into any instrument before it becomes suitable for use in turbulence observations. It is not possible for any one research group to concentrate on the entire instrumental ensemble necessary to extract the full meaning from a given set of observations. For the past four or five years many university groups and government agencies have been working in the field of atmospheric turbulence and diffusion and have concentrated their efforts on accurate measurement of at least one of the variables making up the total turbulence picture. The main purpose of the Great Plains experiment was to bring together the various parts in order to get the maximum scientific returns from the concurrent research in this field.

The organizations participating in the experiments were: Air Force Cambridge Research Center, Air Weather Service (4th Weather Group and 6th Weather Squadron), Wright Air Development Center, Offut Air Force Base, Massachusetts Institute of Technology, Iowa State College, Texas A & M College, Woods Hole Oceanographic Institution, Argonne National Laboratory, University of Wisconsin, University of Texas, University of New Mexico, University of

California at Los Angeles and at Davis, and The Johns Hopkins University. Forecast information was provided by the Kansas City office of the U. S. Weather Bureau. Much of the related research of the university groups is sponsored by the Air Force Cambridge Research Center or by the Office of Naval Research.

Each organization was assigned a definite segment of the observing line. Some instruments were buried in the soil, and some were mounted on 50-foot towers. Observations at higher levels were made by kytoon, rawinsonde pilot balloons, and aircraft of the L20, H19, and PBY types. Conventional double-theodolite pibal observations of the wind and wind gradients were made, and new techniques of photographing the drift of smoke puffs by day and of swarms of pibals at night were tried.

Among the many interesting and novel observational methods introduced during the expedition was one devised by Dr. G. Loeser, who lost his life in a tragic helicopter accident along with five other associates. The technique consisted of dropping a smoke cartridge rack from an elevation of 5000 ft. on which a timer was preset to explode a cartridge at approximately 400-ft. intervals to produce a vertical line of smoke puffs. The three-dimensional positions of the puffs were tracked by a photo-theodolite system at six second intervals. At night, 10 pibals were released in such a fashion that they formed an approximately vertical line at about 400-ft. intervals as they came into the field of view of the cameras. Local high school boys were employed to release the balloons when prearranged signals were fired.

In all, intensive observations were made during 174 hours comprising seven complete observation days. Some of the observation days were not ideal, but on the whole the climatological expectancy of one suitable observational day per week was fulfilled. After reduction, the data will be published by the Geophysical Research Directorate of the Air Force Cambridge Research Center and will then be available to the scientific world.

The authors of this article, who served as coordinators of the expedition, wish to take this opportunity to thank all the participants for their wonderful cooperative spirit during the field program.

Pilot balloons are ready for a nighttime run. The late Dr. Guenter Loeser is seated at the right in the front row.

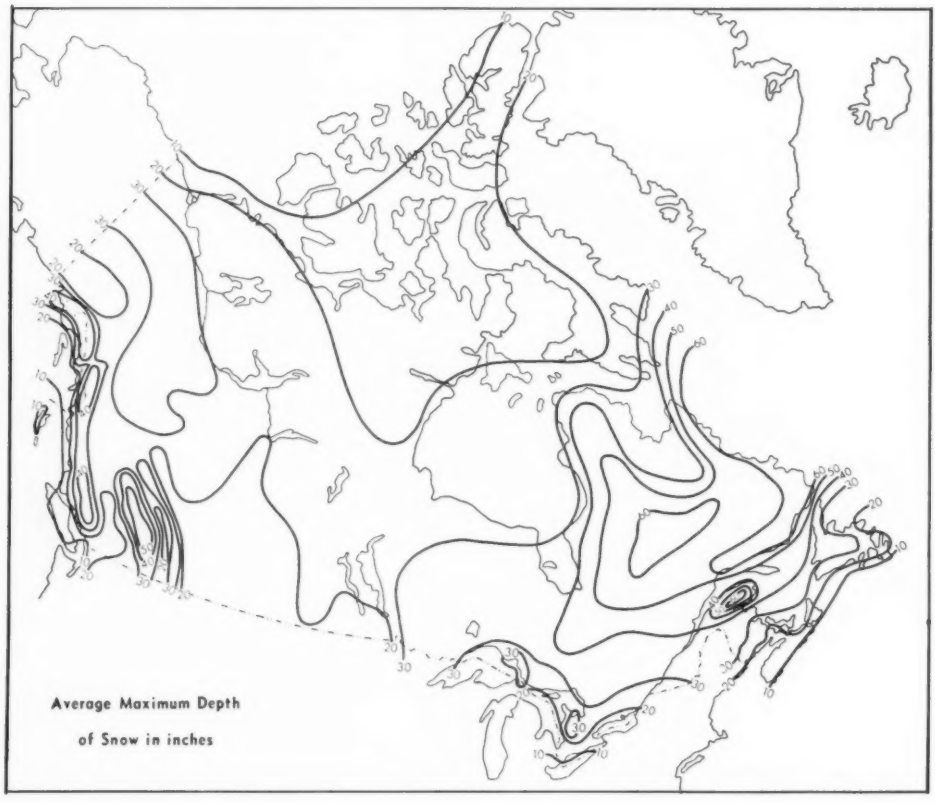
SNOW COVER

(*Continued from page 159*)

area between the isolines for 140 and 160 days. With few exceptions, the major centers of population have developed in the region with a snow cover lasting less than 140 days, and any populated areas north of this line are due to a specialized industry such as the mining communities of northern Ontario.

The number of days between the appearance of the first snow cover for the winter and the disappearance of the last in spring is defined as the season of snow cover. This can be determined by comparing the second and third and should not be confused with the duration of snow cover in the fourth chart. Over most of Canada, the season of snow cover differs from the duration of snow cover by about 20 days. This difference results from early transient snowfalls in autumn and late snowfalls in spring. In these regions the snow cover persists during most of the winter without any breaks. There are a few regions in Canada, however, notably parts of the Maritime Provinces, southern Ontario, southwestern Alberta, and sections of the Pacific Coast where the difference is greater than 20 days. In these areas there can be sufficient melting several times during the winter to remove the snow cover, and the duration may be as low as 50 per cent of the season of snow cover.

In addition to the already mentioned effect of snow cover on transportation, there are many other phases of modern living that must be adjusted to meet the challenge of a heavy snow condition. As an example, it is necessary to make variations in the design of the structure of buildings in different sections of Canada to carry the weight of snow accumulation on roofs. The last chart shows the computed maximum snow load, in pounds per square foot, on a horizontal surface. This chart is the result of work done recently in the Climatological Section of the Meteorologi-

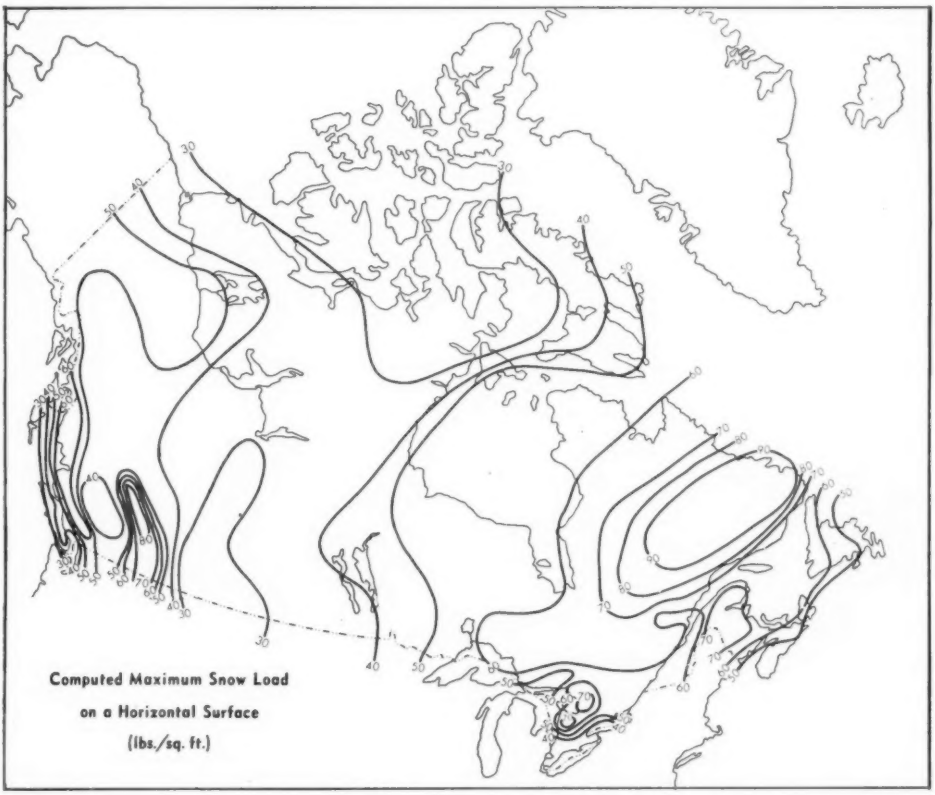


cal Division by Mr. M. K. Thomas for the section on climate which will appear in the Revised National Building Code for Canada. The computed maximum snow loads have been derived from extreme snowfall, snow cover, and rainfall data for 1941 to 1950.

In southeastern Canada, most structural failures due to snow load are reported when a winter or spring rain falls into a heavy snow cover. On the Prairies and in northern Canada a heavy rain is unlikely during the period of maximum snow cover, and the rain factor is not important. The computed maximum snow load was derived by applying a density of 0.2 gram per cc. to the maximum reported depth of snow on the ground during the 10 years and adding to this value the estimated maximum amount of rainfall which might fall into the snow cover in a 24-hour period. As the maximum snow depths occur immediately following a heavy snowfall, it was felt that the average density figure chosen should be somewhere between 0.1 for freshly fallen snow and 0.2 to 0.4 for an old pack.

It will be seen from the chart that the regions of maximum snow load are in the provinces bordering on the Atlantic and Pacific Oceans, with the lightest loads to be expected on the Prairies and in far northern Canada. In some parts of the country there may be a rapid change in snow loading in comparatively short distances. For example, in the vicinity of Lake Huron in southwestern Ontario, the snow load factor doubles in a distance of slightly more than 100 miles.

In conclusion, it should be pointed out that while snow results in many inconveniences to modern living, it has a great economic significance in Canada. Many winter activities and industries are dependent upon an adequate snow cover. In regions where the economy is adjusted to heavy snowfall, winters with subnormal snowfall often cause as much concern as do those with above normal falls.



Weatherwatch

The End of the Prolonged Drought—?

DAVID M. LUDLUM, *Editor*

DROUGHT was the main weather story across the nation in the early fall of 1953 as it had been for many months past. Large sections of the country, particularly in the Southwest, had been in the grips of a prolonged dry period for almost three years, and during the summer and fall of 1953 large additional areas felt the devastating effects of long rainless periods. The concomitant of drought, excessive heat, was present, too, as much above normal average temperatures prevailed across most northern and central sections in late August, September, and early October. New late season maximum records were set in numerous localities in the Middle West. Florida and parts of the Southeast were the only areas that provided exceptions to the general national weather pattern. Very heavy rains continued in the Florida peninsula, and temperatures under cloudy skies were below normal in both months. It was too wet in Florida to do farm work and too dry in the rest of the country even to plow.

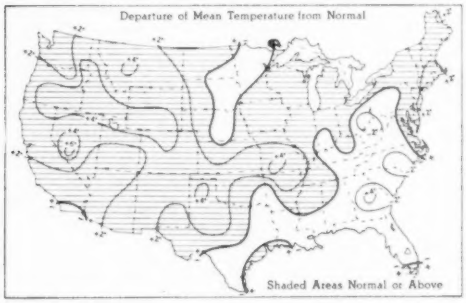
The drought of 1953 fortunately reached its climax in the period under survey. But until the rains came in the Southwest late in October, the drought period had established a record as the most prolonged, if not the most severe, dry period in our nation's recent history. The total precipitation for August, September, and the first three weeks of October did not amount to 50 per cent of normal over half the nation. The particularly dry areas where less than 25 per cent fell during the 11-week period were centered in the Ohio Valley, West Virginia, parts of Missouri, most of Iowa, a few sections from southern Minnesota west-southwestward to northeastern Nevada, and the far southwestern border districts. Most of these sections were declared disaster areas to permit farmers and cattlemen to apply for federal aid to tide them over to the next growing season.

September opened with the entire eastern two-thirds of the country still in the grips of the late season heat wave which was one of the most widespread and severe on record, of the same stature as the great heat waves of the 1930s. In the Ohio Valley and the Northeast September records set in 1918 and 1881 were surpassed as many stations broke all records for late season maximum readings or for prolonged excessive figures. Relief, however, was soon forthcoming as a complicated frontal system over the northern Plains on the 2nd developed into a major depression to bring great quantities of Canadian air southward. The accompanying cold front reached the Chicago area on the night of 3–4 September and the Atlantic Coast sections by the morning of the 6th. The vast continental oven was replaced by a Canadian "deep freeze"; a cool early September period followed, bringing a temperature of 32° at Grantsburg, Wisconsin, on the 7th where readings near the century mark had prevailed only five days previously.

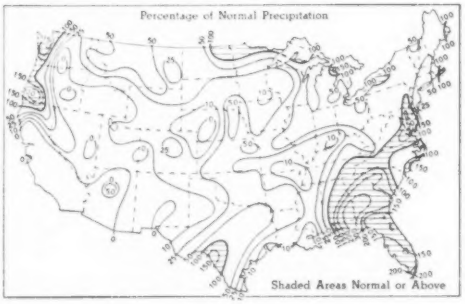
Hurricane **CAROL**, which was at this time driving northeastward from the tropics north of Puerto Rico, failed to recurve northeastward as usual and made almost straight for the great low over eastern Canada. It gave the New England coast a hurricane scare early on Labor Day, and then made a landfall on Nova Scotia where considerable damage was done. Winds at Nantucket Island reached 60 mph, but the rest of the alerted New England coast received only a welcome fall of rain.

While the great Hudson Bay low was deepening

MONTH OF SEPTEMBER 1953



Departure of Mean Temperature from Normal in degrees F.



Percentage of normal precipitation.

to 28.80 inches in the sub-Arctic, a vast western ridge built up over the Plateau and Rocky Mountain areas and became the main feature of the weather map for the greater part of the month. With a hurricane on the New England coast and a tremendous low over Hudson Bay, the western ridge built northward into western Canada and brought a flow of relatively cool, but very dry air to central and eastern sections. The ridge persisted with undiminished strength until the 15th when it flattened out somewhat; all depressions were forced far to the north over central Canada until they could move southeastward in the fast flow that existed at upper levels. Tropical air was excluded from most of the United States and a very dry period ensued. The Atlantic trough became the main scene of disturbances: two hurricanes formed northeast of Puerto Rico and moved in the usual curving course but well offshore. Both **DOLLY** and **EDNA** gave Bermuda a good working over as they passed just to the south only five days apart.

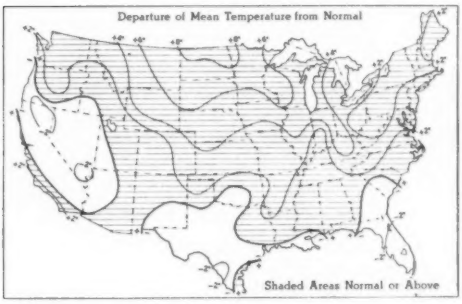
West to east flow predominated throughout the month over western United States with a northwest-southeast component east of the Rockies. Canadian air moved southward on several occasions to bring cool periods. General frosts ended the growing season in the northern Plains and upper Lakes region on the 21st, in northern New York and New England the following day. There were, however, periods of midsummer heat under the western ridge. Many late season maximum records were set during the last week of September: Concordia, Kansas, 105° on the 28th.

FLORIDA RAINS—The principal feature of the precipitation pattern of the month, aside from the widespread drought, was the persistence of heavy rains over the Florida peninsula. Ft. Myers at the southwest tip of the peninsula had a trace or more of rain on every day but one in September. The total fall for the month was 15.58″, and the greatest 24-hour amount was 2.88″. Only three previous Septembers (1947, 1922, and 1853) have had greater September rainfall amounts. And the two-month total at Ft. Myers amounted to 29.89″, surpassed only once before in Sept.-Oct. 1924 when the total was 37.61″. From other Florida points it was the same story of persistent rains. For the greater part of September a trough from the Atlantic Coast trough trailed over the Florida peninsula and separated moist tropical air from the dry air masses that persisted over the interior of the United States. This trough provided a facility for the movement of two tropical disturbances that were just on the borderline of becoming of real hurricane stature. Both originated in the Caribbean Sea to the south and southwest of Cuba, a favorite breeding spot for small late season hurricanes.

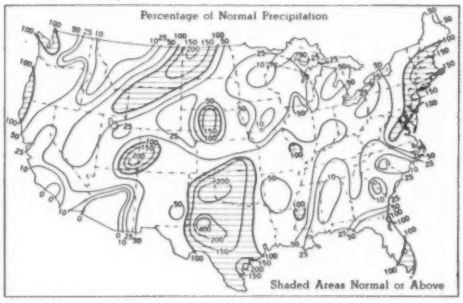
FLORENCE—This tropical disturbance appeared on the 23rd as a westerly moving wave south of Cuba. It passed just to the west of Cuba the next day, and then followed an elliptical path across the Gulf of Mexico and moved inland between Pensacola and Apalachicola about 0900 on the 26th. Pensacola reported a maximum gust at the airport of 75 mph with a sustained 5-minute speed of 35 mph from the north. The lowest barometer read 29.435 inches at 0910. Rainfall totaled 9.09 inches at the airport. At Apalachicola the maximum wind speed was 52 mph from the southeast for one full minute. Rainfall at some inland points in northern Florida reached over 12 inches, but little damage was caused except to increase the flood difficulties. Florence passed off the Georgia coast and joined in the Atlantic trough.

HAZEL—A definite circulation appeared in a trough over the Yucatan peninsula of Mexico on the 7th and took a course to the northeast, passing just west of Cuba and coming inland on the Florida peninsula about 25 miles northwest of Ft. Myers on the 9th. Mr. John W. Holmes in a report furnished to WEATHERWISE reports that the highest sustained wind was 45 mph from the southwest with a peak gust of 62 mph at 11:18 EST. It was at this time that the barometer reached its lowest point, 29.37 inches. Rain fell intermittently for three days with a total fall of 5.02 inches, of which 3.27 fell in a 24-hour period on the 8–9th.

MONTH OF OCTOBER 1953



Departure of Mean Temperature from Normal in degrees F.



Percentage of normal precipitation.

The center passed over Pine Island about 16 miles off the coast where a tornado or waterspout did some damage. At Ft. Myers the main damage was caused by high tides which were 3½ to 4 feet above mean low water. Total damage was estimated at $75,000. **HAZEL** passed across the Florida peninsula on a northeastern track to pass out to sea again just south of Melbourne.

OCTOBER'S CIRCULATION—The mean maps of air flow over the United States for October showed some marked changes from the general heat and drought pattern of September. But the real changes that marked the transition from the fall to winter type of circulation did not become evident until after the middle of October. Western ridge conditions continued to predominate early in the month, and the entire eastern two-thirds of the country was treated to a persistent period of delightful Indian Summer weather. The principal development that changed the pattern over the United States was the deepening and extension of the Aleutian low southeastward. After the 15th low pressure aloft was prevalent over southern California and several depressions formed over the Southwest, usually a sign that storminess will soon break out to the east as moist Gulf air is drawn northward in advance of eastward moving troughs. A further rearrangement of the pressure pattern saw an anticyclone become established in the Gulf of Mexico to rout the trough conditions and rainy weather that had prevailed there for sixty days. The last of October had a western trough-eastern ridge pressure pattern which makes for mild but wet weather in central and eastern sections.

END OF DROUGHT—The development of low pressure in the far Southwest after the 19th signaled the break-up of the drought pattern on the weather map. Light rains over Arizona and New Mexico on the 19th spread northeast and eastward the next day, as a long polar trough took form. Falls of over an inch were reported all along the western High Plains and the eastern slopes of the Rockies on the 20–21st. West and central Texas had very heavy rainfall on the 22nd, and east Texas received the same gift the following day with amounts over much of the erstwhile drought basin amounting to over four inches. The Mississippi Valley and the East received little benefit from this system, but another trough moved eastward from the Southwest on the 25th and spread Gulf air across the central Mississippi and Ohio Valleys where the drought had been most severe. Falls of an inch or more were reported on the 26th, and the rain area reached the Atlantic Coast the next day. The frontal pattern became complicated as the Atlantic seaboard was approached and a secondary formed near Chesapeake Bay. This pushed a warm front northward along the coast with the result that soaking rains fell from Virginia northward. Amounts ranged up to three inches in southern New England. Though the supply of ground water was still inadequate, the drought had been broken and farm work was resumed.

The Restless Atmosphere. F. K. HARE. Hutchinson's Univ. Library, London; Longmans, Green and Co., Inc., New York, 1953. Price $2.40.

For the layman or student who wants to understand the atmospheric processes that cause the storms, clouds, wind, rain, heat, and cold which affect our daily lives and add up to what we call *climate*, this book is the latest, if not the first, to appear in the English language. For the student or teacher who wants to have the climate of a particular place typed or labeled or classified, so he can draw pretty colored charts of a region, a continent, or the world in order to impress the administration of some institution, this book will be a great disappointment, for there is no mention anywhere in the book of the well-known classifications or of the names of the great climatic classifiers of the past generation: Köppen, de Martonne, Supan, etc. Rather the author, a professor of Geography at McGill University, has followed the school of synoptic-aerological or 3-dimensional climatology proclaimed in the 1930's by Bergeron and Flohn in Europe and later by Haurwitz and Austin, Conrad, Jacobs, and others in America. This approach is based on a thorough analysis of existing meteorological data and, where necessary, an extension of the analysis to regions with sparse data, or none at all, by a consideration of the topography and its relation to the movements of air masses, fronts, and actual air flow.

In order to give the reader who does not have an advanced degree in mathematics or physics a simple yet sophisticated picture of the weather and climates of the habitable regions of the earth, the author has had to condense a great deal of information into a few chapters and to limit his subject matter in the first eight chapters to a few of the most important aspects, namely: radiation or energy balance; moisture exchange (clouds, rain, evaporation); stability (convection and turbulence); pressure and wind; cyclones, anticyclones, fronts, air masses; and the effect of the general circulation, oceans, and latitude in creating broad climatic zones on the earth.

Although the title of the book is misleading in that it gives an impression of superficiality, even a casual perusal of the book will dispel this. The title is well chosen since it gives the student the true picture of the atmosphere—a chaotic, ever changing, restless flow of a turbulent, compressible fluid which carries a variable burden of moisture, cloud, dust, etc., and hence a highly variable energy balance, from place to place, from day to day, and even from year to year. The many concrete examples Mr. Hare has used bring this forcefully home to the reader in every page of the book.

MALCOLM RIGBY

AERO PLASTIC RELIEF MAP

This physiographic relief map of the United States is an excellent visual aid for the weather forecaster and student of meteorology. This is the map selected by the U. S. Weather Bureau for display in airport weather stations. It makes a handsome and valuable addition to your office or home study.

DURABLE—Molded from tough, sturdy Vinylite. Built to last . . . year after year.

LIGHTWEIGHT—Only 2¼ pounds . . . so light a child can move it.

LARGE SIZE—64 x 40 inches.

CLEANS EASILY—A damp cloth wipes off all dust, fingerprints and dirt.

SELF-FRAMED—Framed in the same sturdy vinyl plastic as the map itself. Brass grommets. Four small nails support the map . . . anywhere.

SCALE—1″ = 50 miles.

VERTICAL EXAGGERATION—20 to 1.

COLORFUL—Printed in 11 vivid colors to emphasize relief features.

DETAILED—2,000 cites, 600 rivers, 300 national parks, 200 mountain ranges and peaks, and several thousand lakes and reservoirs.

Send for this Decorative, Striking Map . . . Today! — $37.50
fob. Phila.

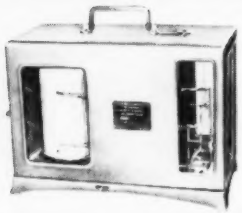
SCIENCE ASSOCIATES

401 North Broad Street **Philadelphia 8, Pa.**

PRECISE

AIR INSTRUMENTATION by BENDIX-FRIEZ

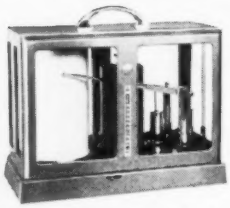
FOR RECORDING TEMPERATURE, HUMIDITY



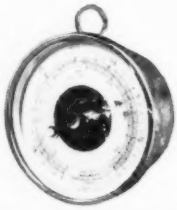
HYGRO-THERMOGRAPH The leader in its field. Noted for precise accuracy and long-time dependability. Portable easy to operate. Widely used in laboratories, factories and offices.

PORTABLE TEMPERATURE, HUMIDITY RECORDER Rugged, compact design. Ideally suited for use in small space and difficult locations. Provides convenient 3 x 5 charts for 10 or 30 hour records.

FOR CHECKING BAROMETRIC PRESSURE



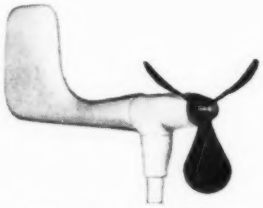
MICROBAROGRAPH A key meteorological instrument. Records atmospheric pressure to within 0.01 inch mercury. Record chart expanded 2½ times for greater visibility.



ANEROID BAROMETER Inexpensive, dependable, easy-to-read. Shows pressure and barometric tendency. Housed in handsome brass case. Favored by professionals and amateurs alike.

FOR MEASURING WIND SPEED, DIRECTION

AEROVANE Indicates and records wind speed and direction. Recognized as "best all-purpose wind measuring instrument yet devised." Readily installed and easily maintained.



WINDIAL A fine precision instrument with large dials that show wind speed and direction at a glance. Popular with smaller airports, yacht clubs, schools, plants, etc.

FRIEZ INSTRUMENT Division of
1412 Taylor Ave., Baltimore 4, Md.

Export Sales: Bendix International Division
205 E. 42nd St., New York 17, N. Y., U. S. A.

Bendix
AVIATION CORPORATION